AS Unit BY2: Biodiversity and Physiology of Body Systems

Name:	Date:

<u>Topic 2.3 Transport (Plants)</u> – Page 2A

		Completed
1.	Read about the structure of phloem tissue pages 2-4 • Answer questions and complete the tasks.	
2.	Look at page 5 and summarise the evidence for phloem being the main tissue involved in translocation.	
3.	Read about the mass flow hypothesis p 6 • Complete all tasks on pages 7-10	
4.	Read about problems with the mass flow hypothesis. Note two alternatives.	

Transport of Organic Substances

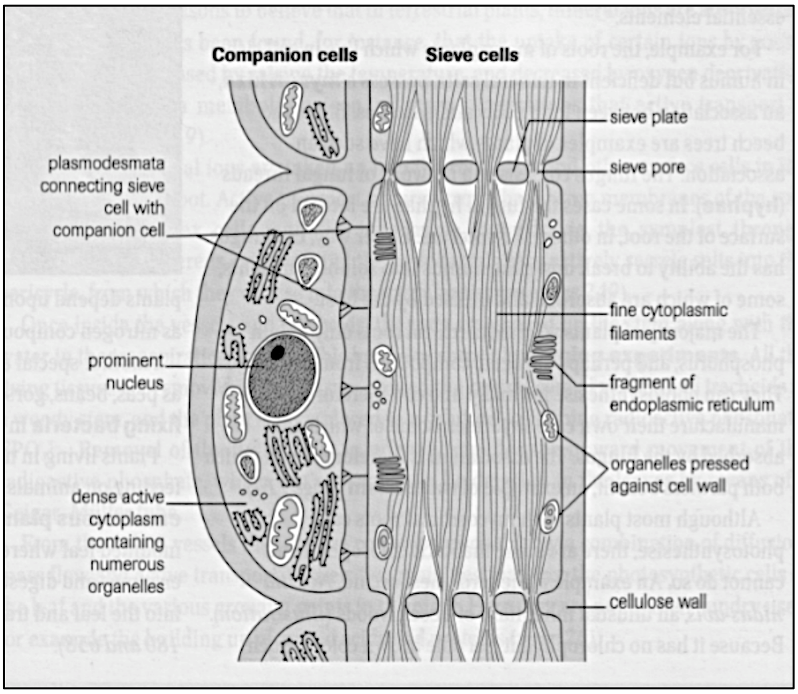
Transport of soluble products of photosynthesis in a plant is called **translocation**, and a number of experiments have been done to show that it occurs in the part of the vascular tissue known as the phloem.

Phloem Tissue
When phloem tissue is observed under a microscope, three main types of cell may be seen: **sieve cells**, **companion cells** and **parenchyma cells**.

Sieve cells lack nuclei, which disintegrate during development. The cells are aligned end to end to form long **sieve tubes** running up and down the plant. It is the sieve tubes form the channels for translocation.

Each sieve cell has perforated end walls known as **sieve plates**. The perforations between one cell and the next are perfectly matched and allow the passage of materials from one to another. The cytoplasm of sieve cells is structurally very simple: it contains no endoplasmic reticulum, mitochondria, plastids or other organelles.

Closely applied to the side of each sieve cell are one or more companion cells, which possess a nucleus, dense endoplasmic reticulum, ribosomes, and numerous mitochondria.

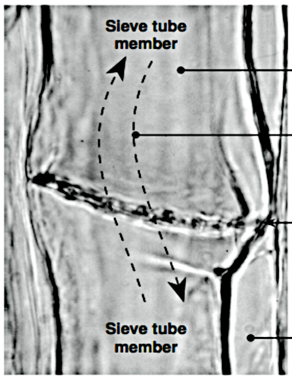


Plasmodesmata connect each sieve tube cell with its adjacent companion cell.

The Structure of Phloem Tissue

Phloem is alive at maturity and functions in the transport of sugars and minerals around the plant. Like xylem, it forms part of the structural vascular tissue of plants.

LS through a sieve tube end plate



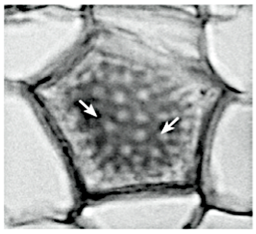
The sieve tube members lose most of their organelles but are still alive when mature

Sugar solution flows in both directions

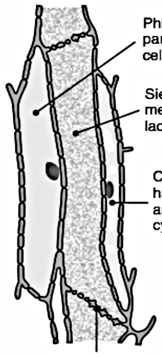
Sieve tube end plate
Tiny holes (arrowed in the photograph below) perforate the sieve tube elements allowing the sugar solution to pass through.

Companion cell: a cell adjacent to the sieve tube member, responsible for keeping it alive

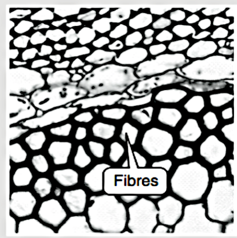
TS through a sieve tube end plate



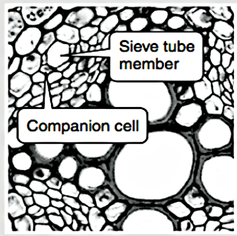
Adjacent sieve tube members are connected via **sieve plates** through which the phloem sap flows.



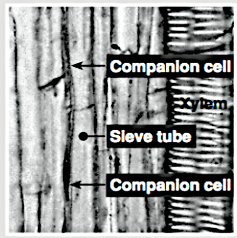
Fibres are associated with phloem as they are in xylem. Here they are seen in cross section where you can see the extremely thick cell walls and the way the fibres are clustered in groups. See the previous page for a view of fibres in longitudinal section.



In this cross section through a buttercup root, the smaller companion cells can be seen lying alongside the sieve tube members. It is the sieve tube members that, end on end, produce the **sieve tubes**. They are the conducting tissue of phloem.



In this longitudinal section of a buttercup root, each sieve tube member has a thin **companion cell** associated with it. Companion cells retain their nucleus and control the metabolism of the sieve tube member next to them. They also have a role in the loading and unloading of sugar into the phloem.



1. Describe the function of **phloem**: ______________________________
2. Describe two differences between xylem and phloem: ______________________________

   ____
3. Explain the purpose of the **sieve plate** at the ends of each sieve tube member: ______________________________

   ____
4. (a) Name the conducting cell type in phloem: ______________________________

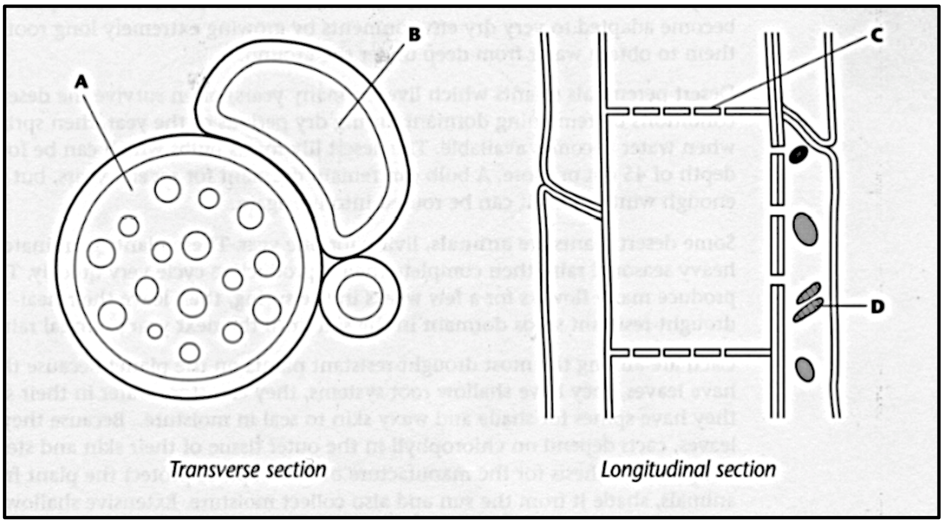
   (b) Explain two roles of the companion cell in phloem: ______________________________

   ____
5. State the purpose of the phloem parenchyma cells: ______________________________
6. Identify a type of cell that provides strengthening in phloem: ______________________________

Phloem transports the organic products of photosynthesis in soluble form as sucrose in a process called translocation. In flowering plants (angiosperms), the sugar moves through the sieve cells, which are arranged end-to-end and perforated with sieve plates to form sieve tubes.

As well as sucrose phloem sap may also contain amino acids, minerals and hormones. Movement of sap in the phloem is from a **source** (a plant organ where sugar is made or mobilised) to a **sink** (a plant organ where sugar is stored or used).

The diagrams below show transverse and longitudinal sections through the same tissue in a plant stem.



Name the cell types A and B.

A…………………………………………………… B……………………………………………………

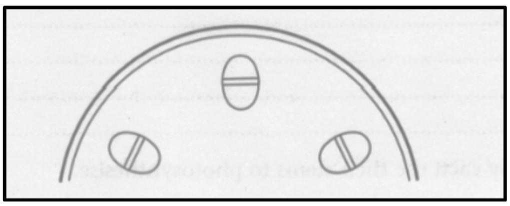
Name the structures C and D.

C…………………………………………………… D……………………………………………………

Cells A and B are important in the translocation of organic solutes from ‘sources’ to ‘sinks’. Explain what a source and a sink mean and give two examples of each.

Describe two ways in which cell B is adapted for its role in translocation.

Radioactive carbon dioxide $^{14}CO_2$ was fed to leaves of a young plant exposed to sunlight. Several hours later, a thin cross-section of the stem was cut and placed on photographic film. Any parts of the plant containing radioactive carbon would cause ‘fogging’ to appear on the film. On the figure below shade in the areas that would cause ‘fogging’ on the film.



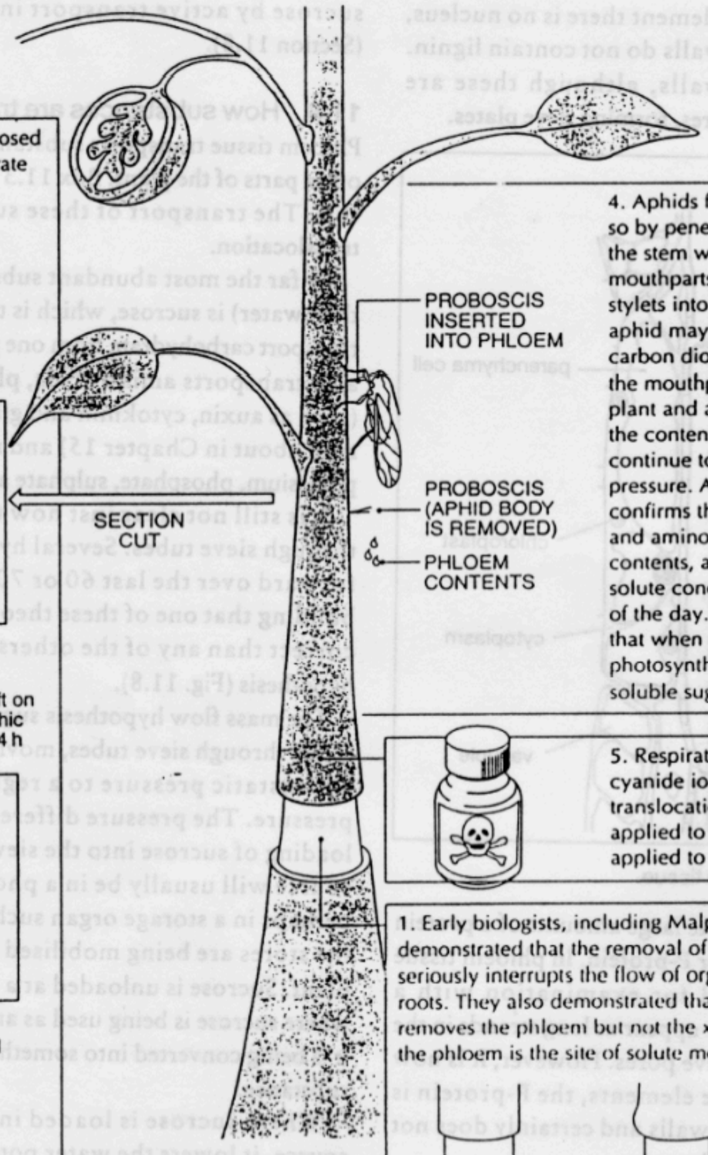
Read the following page, which summarises the evidence that has accumulated to demonstrate that phloem tubes are the sites of both amino acid and sucrose transport.

Describe 3 pieces of evidence that demonstrate that phloem sieve elements are the site of sucrose and amino acid transport.

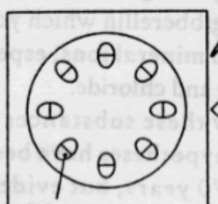
Evidence for phloem as the tissue for translocation comes from the use of radioactive tracers, aphids and metabolic poisons.

The pattern of movement of these solutes within the plant body has also been investigated using radioisotopes, and it has been shown that the pattern of movement may be modified as the plant ages. Up to maturity the lower leaves of an actively photosynthesizing plant may pass their products to the roots for consumption and storage, but once fruit formation begins, ever-increasing numbers of leaves pass their products up to the fruits and eventually even the lower leaves are doing so. Minerals are often remobilized – having been delivered to the photosynthetic leaves via the xylem they may be re-exported through the phloem as the leaves age prior to abscission. The direction of solute movement is under the control of plant growth substances, particularly IAA and the cytokinins.

2. If a mature leaf is exposed to $^{14}CO_2$ it can incorporate ^{14}C into soluble carbohydrates during photosynthesis.

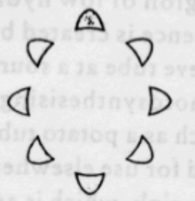


Photographic plate



Phloem

Section left on photographic plate for 24 h

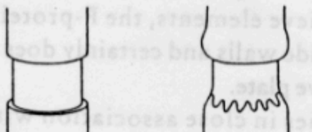


^{14}C largely restricted to phloem when autoradiograph is examined

4. Aphids feeding on plant tissues do so by penentrating the outer layers of the stem with their modified mouthparts and inserting their tube-like stylets into the phloem. A feeding aphid may be anaesthetized with carbon dioxide and the body removed; the mouthparts remain attached to the plant and act as tubes through which the contents of the sieve tubes continue to be forced by hydrostatic pressure. Analysis of these exudates confirms the presence of carbohydrates and amino acids in the phloem contents, and permits comparison of solute concentrations at different times of the day. Results obtained indicate that when conditions favour photosynthesis the concentration of soluble sugars in the phloem increases.

5. Respiratory inhibitors such as cyanide ions (CN^-) reduce or stop the translocation of organic solutes when applied to phloem but not when applied to xylem.

1. Early biologists, including Malpighi and Stephen Hales, demonstrated that the removal of a ring of bark from a tree seriously interrupts the flow of organic solutes down to the roots. They also demonstrated that the ringing procedure removes the phloem but not the xylem, thus indicating that the phloem is the site of solute movements.

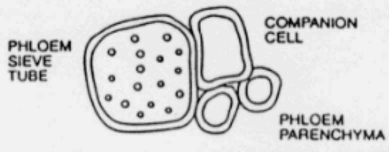


Immediately after ringing: phloem removed, xylem unaffected.

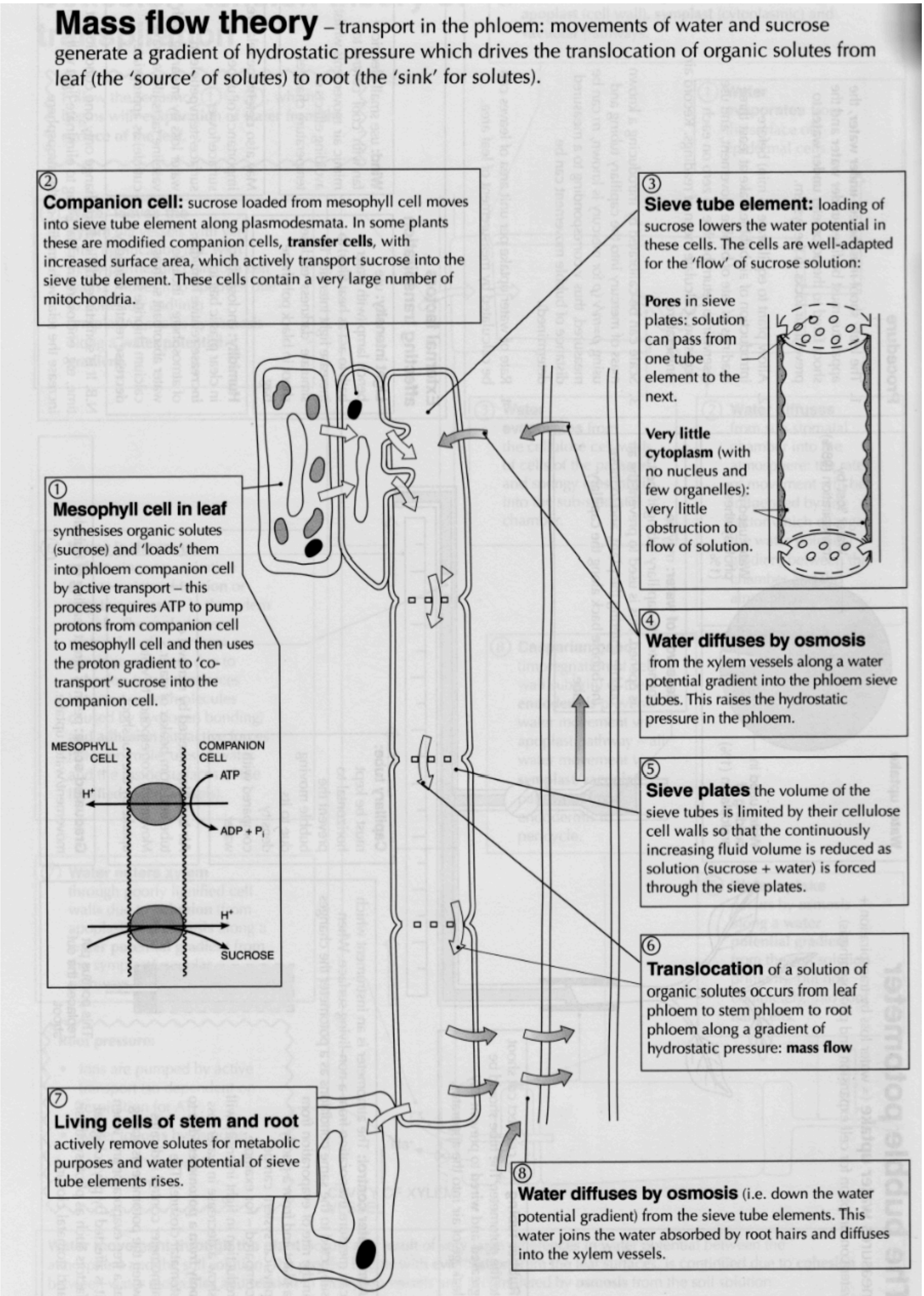
Several weeks later: tissues above ring are swollen with increased solute concentration, tissues below ring show signs of solute depletion.

One–two years later: death – roots have inhibited cell division, thus no growth → death of plant since no water or ion absorption.

3. A combination of electron microscopy and autoradiography (microautoradiography) has demonstrated that sucrose and amino acids are transported in the sieve tube elements rather than in any other cells of the phloem.



Mass Flow Hypothesis
The transport of substances in phloem is known as translocation. It is still not clear how these substances move through sieve tubes. Several hypotheses have been put forward, but evidence is still building that one of these theories is more likely to be correct that any of the others. This is the **mass flow** hypothesis.



The mass flow hypothesis suggests that fluids can flow freely through sieve tubes, moving from regions of high hydrostatic pressure to a region of low hydrostatic pressure. Active loading of sucrose into sieve tubes at a **source c**reates the pressure difference. It lowers the water potential of the sieve tube's contents, therefore water flows into the sieve tube, raising the hydrostatic pressure. Where sucrose is removed at the **sink**, this increases the water p[potential so that water moves out of the sieve tube into the surrounding tissues. This reduces the hydrostatic pressure in the sieve tubes. The difference in pressure causes the fluid inside the tube to flow from source to sink.

SOURCES	SINKS
Photosynthetic tissues: • Mature green leaves • Green stems	Roots that are growing or absorbing mineral ions using energy from cell respiration
Storage organs that are unloading their stores: • Storage tissues in germinating seeds • Tap roots or tubers at the start of the growth season	Parts of the plant that are growing or developing food stores: • Developing fruits • Developing seeds • Growing leaves

Sometimes sinks turn into sources, or vice versa. For this reason, the tubes in phloem must be in **either direction** to transport biochemicals. There are however, **no valves or central pumps** in phloem and so **energy** is needed to generate the pressure required for transport. Consequently, the movement of substances in phloem is called **ACTIVE TRANSLOCATION**.

Solutes are loaded into the phloem sieve tubes (a process requiring ATP), and then solutes flow through the phloem from a region of high hydrostatic pressure to a region of low hydrostatic pressure. Hydrostatic pressure is high in and around photosynthesising cells in the light (mesophyll cells of the leaf), and in phloem sieve tubes nearby, because of the presence of sugar, which generates a high osmotic pressure.

1. What will happen due to presence of sugar in terms of water movement? What process causes this to occur and what effect will this have on the hydrostatic pressure inside the phloem?

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2. Is this area a source or a sink? Explain your answer.

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Hydrostatic pressure is low in cells where sugar is converted to starch and stored.

3. Give two examples of cells that are in this condition.

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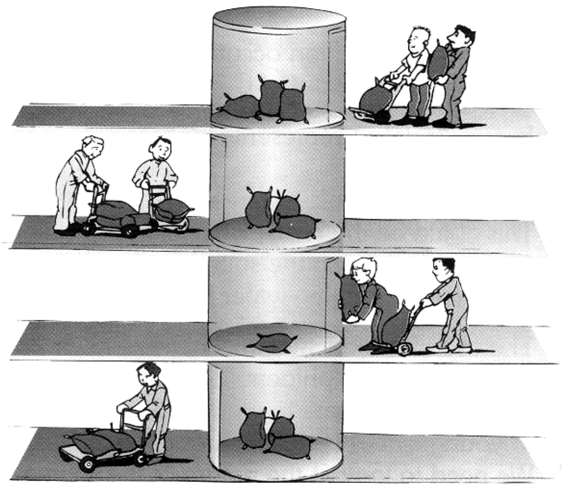
4. This low hydrostatic pressure will also apply to the nearby phloem sieve tubes. Here the removal of sugar lowers the osmotic pressure, and water flows away. Starch storage cells like these are called __________ areas.

Label the phloem tube, sieve plates, source and the sink in this diagram. Give an example of the source and sink.


'Sucrose sir? At your service'

5. Describe the differences between **transpiration** and **translocation**.

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6. Complete the following tables comparing xylem and phloem:

STATEMENT	XYLEM	PHLOEM
May contain tracheids		
Contains cells with living contents		
Contains lignified cells		
Transports organic products of photosynthesis		
Unidirectional transport		
Transport inhibited by metabolic processes		

FEATURE	XYLEM	PHLOEM
Name of conducting cells		
Direction in which materials are transported		
One possible mechanism by which materials are transported		

The table below shows the concentrations of two chemicals in the phloem and xylem sap of the white lupin, *Lupinus albus*.

CHEMICAL	XYLEM (mg litre $^{-1}$)	PHLOEM (mg litre $^{-1}$)
Sucrose	Not detected	154000
Magnesium	27	85

7. Why do you think that the concentration of sucrose and magnesium differs in xylem and phloem?

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Problems with the Mass Flow Hypothesis

Phloem tissue frequently transports substances in opposite directions and rates and at the same time. This is clearly impossible if you imagine fluids flowing in opposite directions or at different rates in the same sieve tube. However, it is easy to explain if you consider that phloem tissue contains many sieve tubes and it is possible for fluids to be travelling in opposite directions in two different but nearby tubes.

Alternative Hypotheses

- **Electro-osmosis theory –** Proposes that K^+ are actively transported into companion cells, across the sieve plate. The movement of the ions drawn across the polar water molecules across the plates.
- **Cytoplasmic Streaming** – Transcellular strands, which extend from cell to cell via pores in the sieve plate, carry out a form of cytoplasmic streaming.